fiber optic cables are buried at the toe of a crib wall used to support the southbound alignment of I-15. Figure 14 shows the surface water in this region, which was identified as a potential liquefaction region. Figure 15 shows the conduits hung under a water distribution system pipe, both of which are supported from a road bridge over a railroad. Other important collocations include where the conduits are buried near buried fuel pipelines, a number of which are in liquefaction or landslide prone regions.

In all of these cases, the fiber optic cables are at potential risk because the light anchors used could be expected to fail due to shaking. The heavy water pipe just above the fiber optic cable conduit can be expected to fall on and fail those cables.

The analysis of the fiber optic cable systems indicates that they are not at significant risk until the MMI values equal VIII or more. In the Cajon Pass that occurs at liquefaction areas or at the San Andreas fault where surface displacements of up to 12 meters are anticipated. Thus, shaking damage is not expected to be significant compared to displacement-related damage. However, the screening method data base does not directly account for the light anchors and the conditions of the conduits as shown in the figures. It is possible that they are more sensitive to shaking damage than the screening method predicts.

At the San Andreas fault location (just north of and close to Blue Cut) the fiber optic conduits are not collocated with other lifelines within the zone of influence of the lifeline. Thus, for purposes of this study there is no collocation impact there. However, the large number of near by lifelines does suggest that general construction congestion could delay the permanent repair of the communication lifelines in this region. Also, it probably would be possible to temporarily lay the fiber conduits on the ground surface, restoring service on a temporary basis. These types of changes to the assumed restoration of service time are noted, but they were not used in the present study to estimate the service restoration time.

Four liquefaction regions have the potential to impact the fiber optic systems. At the liquefaction region just southeast of the I-15/I-215 interchange, the fiber optic cables are in separate and dispersed conduits. However, two cable conduits cross this zone near the railroad beds. One cable conduit crosses the 16-inch natural gas pipeline and the 8-inch petroleum products pipeline, and then it runs parallel to the 8-inch line. Another cable conduit crosses the liquefaction zone and is perpendicular to the 16-inch natural gas pipeline, which is also in the liquefaction zone. The liquefaction impact is calculated as a damage state 7 (catastrophic) but it only has a 40% probability of occurring. The conduit repair time in this region is hypothesized to triple, based on the delays required to repair the natural gas and the petroleum products pipelines and the delays associated with the repair of the nearby damaged I-15 and railroad bridges. This causes the fiber optic conduits' most probable repair time to increase by about ten days.

In the second liquefaction region the four cable conduits are collocated and they are parallel and next to the 8-inch and 14-inch petroleum products pipelines. In this region they cross over the 36-inch natural gas pipeline. The liquefaction impact is a damage state 7 with a 20% probability of occurrence. The collocation damage scenario assumed that the petroleum product pipelines would have to be repaired before the fiber optic cables could be replaced within their conduits along their old route, causing a 55 day delay in being able to access the five fiber optic cables. Another 10 days delay for equipment availability is expected. However, the low probability of liquefaction resulted in the most probable restoration time increasing by only about four days.

The third liquefaction zone is just south of Blue Cut. The collocated lifelines include the fiber optic conduits, fuel pipelines and a high voltage power line also crosses over the region. The liquefaction probability at this locations is estimated at 50%. Most of the repair activities for the power line will not impact the fiber optic cable conduit repair. The only impact could come when the power lines directly over the conduits are being worked on. The most probable restoration time increased by only about 12 days.

The fourth liquefaction zone is where the fiber optic conduits cross the toe of an I-15 retaining wall crib and then are connected along the concrete culvert under I-15 (see Figures 13 and 14). The concrete culvert is a massive structure, and its damage is expected to be small. Analysis of the crib wall found that its movement would not substantially impact the highway, however, just partial movement of the crib wall could severely damage the fiber optic cables. In such a case they could not be replaced permanently until the wall had been stabilized. Fortunately, the probability of liquefaction is only 40% in this region, resulting in the 140 day crib wall-induced delay becoming a 22 day most probable restoration time increase for the fiber optic conduits.

Where the AT&T and WTG cables are hung from the bridge over the Southern Pacific railroad is the final collocation damage location where the collocation impacts were found to be serious (see Figure 15). There, because the shaking intensity is only MMI=VII, not much damage would normally be expected to the cable conduit itself. However, the wall brace and anchor supports for the water pipe and the fiber optic conduit are small and have not been sized for earthquake conditions. Thus, it was assumed that they fail allowing the fiber optic conduit to sag. The heavier water pipe was assumed to fall on top of the fiber optic conduit which is located directly under it, causing the fiber optic conduit to rupture and fail. The probability of this failure scenario is estimated to be 80%, causing the most probable restoration time to increase by about 4 days.

Thus, of the 55 collocations analyzed for the fiber optic systems, nine were estimated to lead to increased probable times to restore service. Most of these conditions resulted from ground motion-induced failures, and the impact on the fiber optic systems was that the failures of the other collocated lifelines lead to increases in the delay time before the fiber optic systems could be repaired. The practice of collocating all of the fiber optic conduits together, along with the practice of hanging them from bridges and culverts with very light anchor bolts, suggests that in future earthquake situations the loss of telephone communications will be more severe than have been experienced in the past. That is because the loss of a few hard-wired telephone lines in past earthquakes has not been significant in terms of the ability of the systems to handle call traffic. Fiber optic cables, however, handle many more calls per line than does a hard-wired system, and if one cable is lost then probably all of the collocated cables will be lost in the same event.

The overall estimate of the impact of collocation on the communication lifelines was:

Lifeline	Increase in Probable Time to Restore Service, days	Increase in Probable Time to Restore Service, %
Fiber Optic Cables	61	86

Electric Power Lifelines

Figure 16 shows the electric power transmission lifeline routes in the study area. The location of the photographs presented in this section of the report are also shown on the figure. Experience has shown that power transmission towers are quite resistant to earthquake shaking, principally because of the conservative wind loading criteria used in their design. Thus, only fault displacement, landslide, or liquefaction are expected to caused significant levels of damage to the towers.

The electric power lifeline systems include a major transmission system substation at Lugo in the northeast corner of the study area, a hydroelectric generation station in Lytle Creek Canyon, and four major high voltage transmission systems. The hydroelectric station is not collocated with any of the lifeline components of interest to this study. Although the substation is collocated with two of the high voltage transmission systems, component failures in the substation are not expected to lead to transmission line failures, and visa versa. The transmission lines are not expected to have any failures at the shaking intensity expected at Lugo

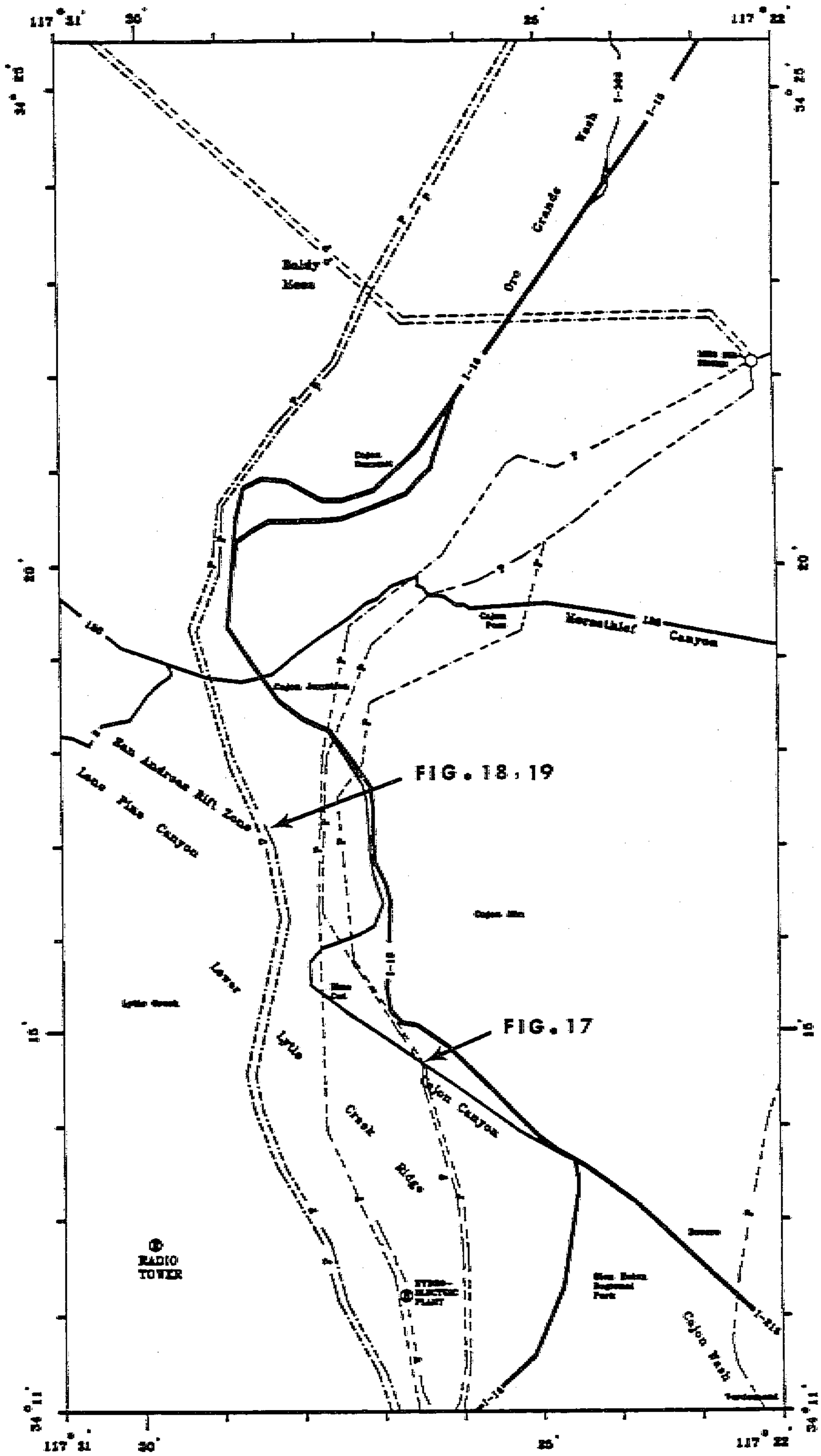

Figure 16, ELECTRIC POWER LIFELINE ROUTES

SCALE

0 1 2 MILES

0 1 2 KILOMETERS

N

Larger Scale Figure Located at End of Document

EXPLANATION

I-15		INTERSTATE
2		PAVED HIGHWAY
P	P	POWER LINES
W	W	BURIED AQUEDUCT

(where MMI = VII). Thus, although the substation is a potential weak link in the overall electric power transmission system, the lack of collocation impacts means it was not be examined further in the present study.

In general, power transmission lines are not impacted directly by the other lifelines, as they are either above or otherwise outside of the zone of influence of the other lifelines. However, they can be impacted by construction delays or fires induced by the failure of other lifelines. The general tower design and footings used are quite rugged and earthquake resistant (resistant to shaking damage). There have been some cases when shaking has caused the lines themselves to gallop or vibrate, resulting in their coming close or even touching other lines routed on the same tower. The resulting arc and electrical short can cause fires and/or drop both lines from service. However, this failure mode is not addressed in the available data base and thus was not considered in the present study.

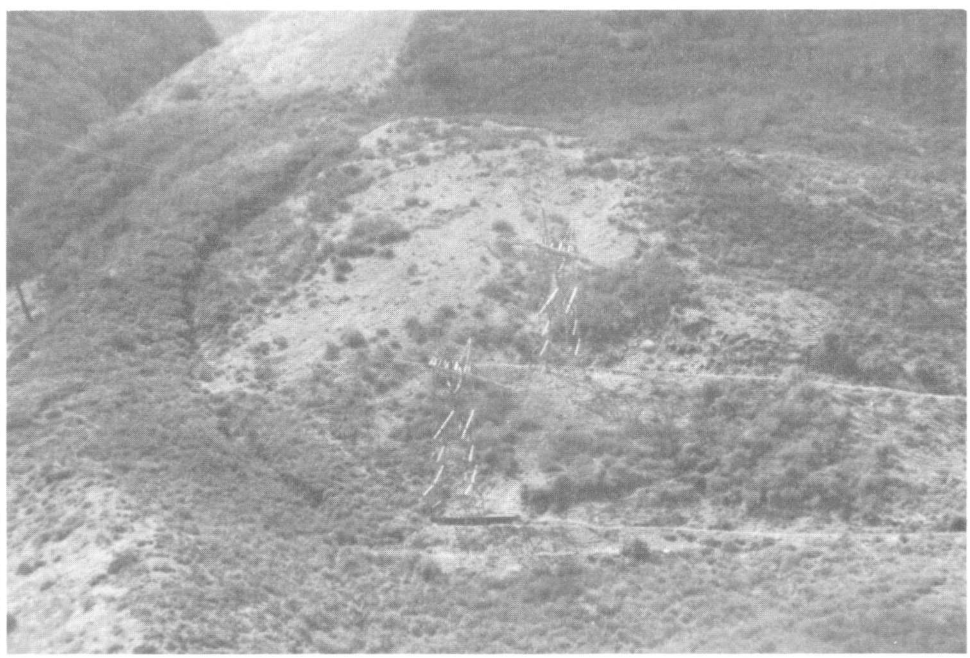

Figure 17 A Landslide Scar With Power Towers In The Slide Area

Transmission lines often traverse more rugged areas, and as such they are susceptible to landslide damage. Figure 17 shows two transmission towers located in an old landslide scar (the original towers were damaged in the landslide). This location is an important collocation site, as a buried natural gas transmission pipeline and the railroad tracts are located just below the slide area. Figure 18 shows the location of two high voltage power transmission tower systems, a buried natural gas transmission pipeline (shown by a surface marker), and the 8- and 14-inch buried petroleum products pipelines (also shown by a surface marker).

This location is in the fault rift zone of the San Andreas fault (in Lone Pine Canyon). Figure 19 is a photograph from the same location looking in the opposite direction. It shows a transmission tower located at the edge of a steep ravine where it is subject to possible landslide failure. This general location (in the San Andreas fault and rift zone) is the most significant collocation condition for the electric and the fuel lifelines.

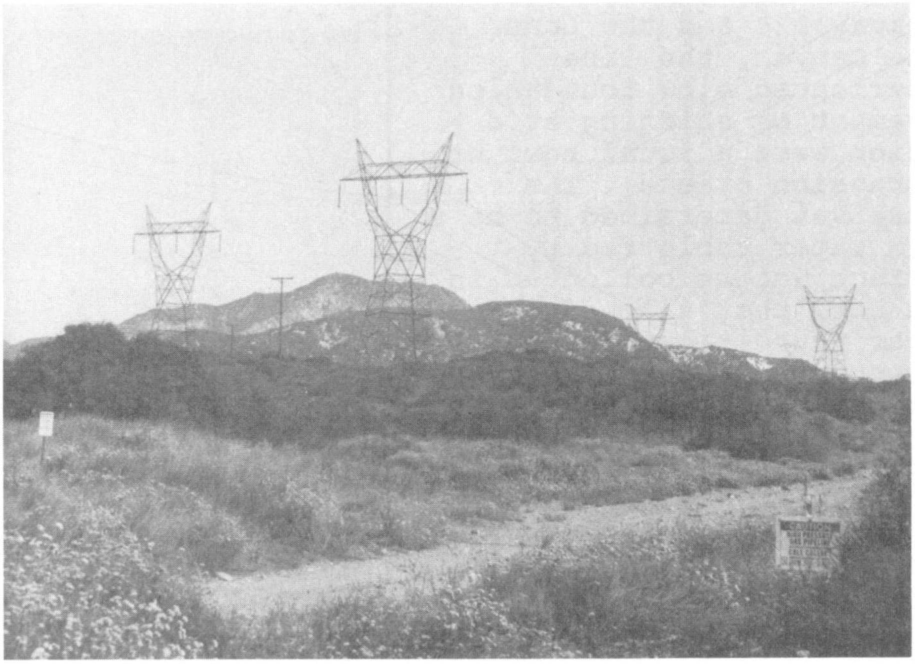

Figure 18 Power Lines, Natural Gas & Petroleum Products Pipelines Intersection Over the San Andreas Fault Rift Zone

The Southern California Edison (SCE) 115 kV Arrowhead:Calelectric Shannin transmission line (located in the southeast corner of the study area) is routed through some local landslide and liquefaction zones, however, it is not collocated at those regions. Its other collocation impacts were negligible. In the northern section of the study area the SCE Lugo-Vincent two-line, 500 kV transmission lines traverse from Lugo station west and then northwest. Because of the low shaking intensity (low for power lines), they only experience damage state 1 or 2. Thus, these two SCE transmission systems are not of interest for collocation impacts in the present study. There are, however, a Los Angeles Department of Water and Power (LADWP) two-line transmission system and a three-line SCE transmission line system that resulted in collocation impacts.

The LADWP Victorville:Century 287.5 kV transmission line system (it has two full circuits) extends from the north (located at about the center of the northern boundary of the study area) to the south of the study region. It was constructed in 1936 to transmit power from the Hoover Dam in Nevada to the Los Angles Basin. It has been upgraded in 1970, 1974 and 1980 to allow switching between the 287.5 and other 500 kV lines as well as to add new controls. Parts of the line have previously experience problems of interest to this